# POPULATION SIZE OF BOTTLENOSE DOLPHINS *(Tursiops truncatus)* IN CARDIGAN BAY (Special Area of Conservation), WALES

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## DEDICATORIA

Este trabajo esta dedicado a todas las personas que a pesar del tiempo y las dificultades nunca dejaron de creer en mí.

## DEDICATION

This work is dedicated to all people who in spite of the time and difficulties never let believe in my.

»Cada vez se reconoce más que nuestro entendimiento de la biología y la dinámica poblacional de los cetáceos van a permanecer inadecuados en un futuro previsible. De este modo, siguiendo el principio de precaución, necesitamos estar preparados para actuar …«

»It is increasingly recognized that our understanding of cetacean biology and population dynamics is going to remain inadequate in the foreseeable future. Thus following the precautionary principle, we need to be prepare to act …«

**Whitehead 2000**

## AGRADECIMIENTOS

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## ABSTRACT

Bottlenose dolphin's (*Turpsios truncatus*) Cardigan Bay population has been protected since 1992, although the management plan was implemented in 2001. Nonetheless, how the population size has responded to these strategies since then has not been evaluated. In order to achieve this goal the population size was calculated from 2003 to 2005, and compare with information collected in the past. The annual monitoring of the Sea Watch Foundation was used to estimate *T. truncatus* abundance. The population size was estimated assuming a close population, using photo-ID data and mark-recapture method by ($\boldsymbol{M_{th}}$) model. Most of the sampled individuals in the population were catalogued as frequent and common, showing a permanent resident population, with a 40% of the marked animals seen during two consecutive years (high capture frequency). Non statistical difference was found in the estimated population size between 2003 and 2005; although there was an increment in the population size of 16% during that period. Data suggest a growing population in the last sixteen years, which in part can be due to conservation strategies, though this hypothesis most be confirmed in consecutive monitoring.

# 1. INTRODUCTION

Since Cardigan Bay is an important location for bottlenose dolphins in the U.K., with significant number of individuals known to occur regularly, it has been declared as a Special Area of Conservation in order to maintain the dolphin population in a favorable status. Although several studies have been carried out on the Cardigan Bay bottlenose dolphin (*Tursiops truncatus*) population, the status and the trends of this population were relatively poorly known. The main aim of this study was to calculate the population size of bottlenose dolphin in Cardigan Bay, during three consecutive years (2003 to 2005), in order to determine its status and trend of the population, as well as how this population has responded to the management plan that has been implemented since 2001.

This study forms part of the Sea Watch Foundation's long-term monitoring program, necessary since dolphins are long lived animals; therefore a long term monitoring is indispensable to acquire reliable results when evaluating populations. This survey was not only a small step towards the understanding of this population; but it also proposed the unification of the methodologies by comparing the results obtained by different teams throughout past years of research. Consequently, in order to describe the real status of the bottlenose dolphin population in Cardigan Bay, the results obtained in this survey need to be confirmed with other similar studies in the future.

# 2. THEORETICAL BACKGROUND

## 2.1. Bottlenose Dolphins

The order Cetacea is subdivided in two suborders: Mysticetes, that are all the baleen whales, and the Odontocetes that are the toothed whales. The bottlenose dolphin *(Tursiops truncatus)* (Montagu, 1821) belongs to the suborder of Odontoceti and the family Delphinidae. Although biochemical evidence supports the existence of several geographical subspecies, most scientists currently recognize only two species of bottlenose dolphin (Rice, 1998). This species is probably one of the best studied among the cetaceans.

This genus shows large variation between individuals in size, shape and colour depending on the geographical region in which they live. There are two main varieties: a smaller inshore form and a larger and more robust one that lives mainly offshore (Duffield & Chamerlin-Lea, 1990). It is well known that the inshore populations occupy a diverse range of habitats, including many enclosed seas such as the Red, the Black and the Mediterranean, as well as open coasts with strong surf bays and channels, lagoons, large estuaries, and the lowest of the rivers. Inshore populations, are generally found in depths up to 30m. It is possible that many of those populations are resident year-round, whilst offshore populations are highly transient undertaking seasonal migrations (Shane, *et al.,* 1986; Wells & Scott, 1999).

**Figure 1**: Bottlenose dolphin (*Tursiops truncatus***)**

*Tursiops truncatus* is extremely common worldwide species in temperate and tropical waters, being absent above approximately 45 Celsius degrees in either hemisphere (Reeves.*et al.,* 2002) In the Pacific Ocean, bottlenose dolphins are found from northern Japan and California to Australia and Chile. They are also found offshore in the eastern tropical Pacific as far west as the Hawaiian Islands. In the Atlantic Ocean they are found from Nova Scotia and Norway south to Patagonia and the southeast tip of South Africa. Bottlenose dolphins are also found in the Mediterranean Sea, and in some areas of the Indian Ocean from Australia to South Africa (Figure 2). Variation in water temperature, migration of food fish, and feeding habits may count for the seasonal movements of some dolphins to and from certain areas (Shane, *et al.,* 1986; Duffield & Chamerlin-Lea, 1990). Some coastal dolphins in higher latitudes show a clear tendency toward seasonal migrations, travelling further south in the winter. Those in warmer waters show less extensive, localized seasonal movements (Shane, *et al.,* 1986).

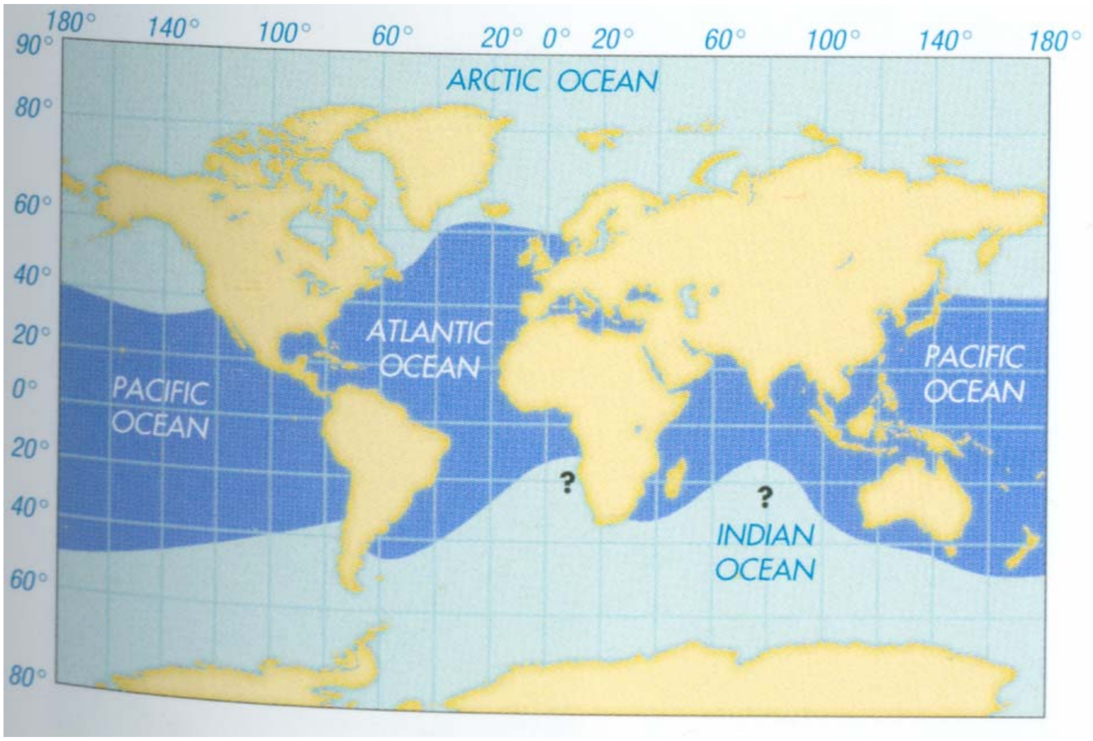


**Figure 2:** Yellow areas show the range of the Bottlenose Dolphin (*Tursiops truncatus).*

Bottlenose dolphins are long lived mammals, as females can live for more than 50 years and males for more than 40. Females start breeding at five to thirteen years of age and have a minimum inter-birth period of three years. Males reach sexual maturity at an age of eight to thirteen years, and calves are born throughout the whole year. However, certain breeding seasons have been observed in some locations, and they generally coincide with calving seasons (Schroeder, 1990; Hansen, 1990). After 12 months of gestation the female gives birth to a single offspring that remains with its mother for three to five years (Schroeder, 1990; Hansen, 1990).

Bottlenose dolphins are powerful swimmers with a foraging and travelling speed of 5 – 11 km/hour but can reach a speed of 29 – 35 km/hour (Fish &

Hui, 1991). In coastal waters, dives rarely last more than 3-4 minutes, but may be longer in oceanic animals, which can dive to depths of 600m for 15 minutes.

Bottlenose dolphins are active predators and eat a wide variety of fish, as well as some cephalopods (squid and octopus), and occasionally shrimps and small rays and sharks. The foods available for a dolphin vary with its geographic location (Barros & Odell, 1990). Bottlenose dolphin feeding behaviour, social structure and reproduction vary from population to population, according to differences in their local environment (Wells & Scott, 1999).

The social structure of the bottlenose dolphin is based on groups called pods. A pod is a coherent long-term social unit (Scott, *et al.,* 1990). In general, the size of pods tends to increase with water depth and openness of habitat. Several bottlenose dolphin studies have demonstrated that larger groups of *Tursiops* occur in open and deeper habitats. This may be correlated with foraging strategies and protection (Shane, *et al.,* 1986). Protected habitats (i.e. bays) may attract small populations of resident individuals (Wells *et al*., 1997), which does not necessarily mean that all members of the community are present at all times (Würsig & Harris, 1990). There can be varying degrees of site fidelity resulting in resident and semi-resident animals (Weller & Würsig, 2004). It also has been suggested that bottlenose dolphins inhabiting seasonal, higher latitude, areas are more likely to exhibit a migratory behavior (Shane, *et al.,* 1986). Cardigan Bay populations seem to have long-term site fidelity, but It is not known whether these dolphins are seasonally resident or remain in Cardigan Bay all year round. However, a decrease in the number of sightings from November to March suggests that the dolphins are seasonally resident (Bristow, 1999), although it is true that no dolphins identified in Cardigan Bay have been re-photographed in other regions, that is almost certainly because although dolphins are seen regularly in the northern Irish Sea off NW England, the Isle of Man, and SW Scotland, they have not been photographed so it has not been possible to say whether Cardigan Bay animals have occurred there (Evans personal communication 2006).

The IUCN classified the bottlenose dolphin (*Turpsios truncatus)* as “data deficient” (i.e. insufficient data of population density or trends along its distributional range), because there is not sufficient information to evaluate its conservation status (Culik, 2004). This species is not considered threatened or endangered, but a special protected status was given under Annex II of the European Union’s Habitats Directive (Ceredigion Country Council *et al.,* 2001). Currently, no estimates of worldwide population size exist (coastal and pelagic); although there are some estimates for specific regions or areas (Table 1).

However, most of the data in the literature do not mention the sample area to estimate density or they utilize different methodologies to calculate population size (Table 1). The use of different techniques does not allow population size comparisons, or estimates of a global population size, and even less the definition of population dynamics. Despite all these difficulties, it is believed that a number of *Tursiops* populations are dramatically reducing in size such as in the Black Sea (ACCOBAMS, 2004), Indo-Pacific Sea (Stensland *et al.,* 2006), Northern Adriatic Sea (Bearzi *et al.*, 2004), and Eastern Ionia Sea (Bearzi *et al.,* 2005).

**Table 1:** Bottlenose dolphin abundance, density, tendency and site fidelity in various studies in the Atlantic, Pacific, Mediterranean and the Black Sea. Where 95% CI confidence interval, CV coefficient of variation, - no data available, * no data about the year of the study were found but were replace with the publication year.

| PLACE | YEAR or PERIOD OF TIME | ABUNDANCE | DENSITY ind/Km2 | TENDENCY | SITE FIDELITY | REFERENCE |
|---|---|---|---|---|---|---|
| **ATLANTIC** | | | | | | |
| **Western Galveston Bay Texas (USA)** | 1997-2001 | 28-38 | 0,94-1,01 | - | Site fidelity | Irwin & Würsig (2004) |
| **Mississippi Sound Louisiana (USA)** | | | | | Long-term site fidelity | |
| Summer | 1995 | 584 (CV=0,17) | 1,3 | - | | Hubard *et al.* (2004) |
| Fall | 1995 | 268 (CV=0,23) | 0,6 | - | | Hubard *et al.* (2004) |
| **Drowned Cayes Belize** | 2005 | 122 (95% 140-104) | - | - | Low site fidelity | Kerr *et al.* (2005) |
| **Indian River Lagoon Florida (USA)** | 1977 | - | 0,68 | - | Long term site fidelity | Leatherwood (1979) in Shane *et al.* (1986) |
| **Gulf of Mexico** | | | | | | |
| Eastern | 1994 | 9.912 (CV=0,12) | - | - | - | NOAA (2006) |
| Northern | 1993 | 4.191 (CV=0,21) | - | - | Site fidelity | NOAA (2006) |
| | * 1978 | - | 0,23-0,44 | - | - | Leatherwood *et al.* (1978) in Shane *et al.* (1986) |
| Western | 1992 | 3.499 | - | - | - | NOAA (2006) |
| **Texas Corpus Christi Bay and Aransas Pass** | 1979 | 103 95%CI 67-139 | 1,02 | - | - | Leatherwood & Show (1980) in Chapmand & Feldhamer (1982) |
| **Mississippi coast (sounds)** | 1974 | 1.342 95%CI 495-2,189 | 0,14 | - | - | Letherwood *et al.* (1978) in Shane *et al.* (1986) |
| | 1975 | 879 95%CI 511-1.247 | 0,09 | - | - | Letherwood *et al.* (1978) in Shane *et al.* (1986) |
| **Mississippi Coast (marshes)** | 1974 | 438 95%CI 144-732 | 0,13 | - | - | Letherwood *et al.* (1978) in Shane *et al.* (1986) |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Louisiana Coast** | 1975 | 897 95%CI 436-1,358 | 0,09 | - | - | Letherwood *et al.* (1978) in Shane *et al.* (1986) |
| **Tampa to Hudson** | 1979 | 1.397 95%CI 1.291-1.503 | 0,61 | - | - | Leatherwood & Show (1980) in Chapmand & Feldhamer (1982) |
| **Texas Gulf coastal waters off Padre and Mustang island** | 1979 | 300 95%CI 226-374 | 0,31 | - | - | Leatherwood & Show (1980) in Chapmand & Feldhamer (1982) |
| **Florida Gulf Coast (USA)** | * 1982 | - | 0,06 | - | - | Leatherwood & Reevs (1982) in Shane *et al.* (1986) |
| | 1979 | 1.190 95%CI 964-1.416 | 0,52 | - | - | Leatherwood & Show (1980) in Chapmand & Feldhamer (1982) |
| **Moray Firth (Scotland)** | 2003 | 108 (95%CI 117- 99) | 0,16 | - | - | Culloch (2004) |
| | 2004 | 61 (95%CI 72-50) | 0,16 | - | - | Culloch (2004) |
| **North Carolina bays, sounds and estuaries (USA)** | 2002 | 1.033 (95%CI 860-1.266 CV=0,099) | - | - | - | Read *et al.* (2003) |
| **North Carolina Cape Hatteras** | 1884 | 13.740-17.000 | - | - | - | Mitchel (1975) in Chapmand & Feldhamer (1982) |
| **Cardigan Bay (Wales)** | 1989-1998 | 158-235 | **-** | **-** | **-** | Lewis (1999) in Bains *et al.* (2000) |
| | 1990-1993 | 127 | - | - | - | Arnold *et al. (*1997) |
| | 2001 | 215 | 0,2 | - | - | Baines *et al. (*2002) |
| **Texas Gulf coast (USA)** | 1978 | - | 0,75 | - | - | Barham *et al.* (1980) in Shane *et al.* (1986) |
| **Pass Cavallo Texas (USA)** | * 1981 | - | 0,93 | - | - | Gruber (1981) in Shane *et al.* (1986) |
| **Corpus Chisti Bay Texas (USA)** | 1979 | - | 1,02 | - | - | Leatherwood & Reevs (1983) in Shane *et al.* (1986) |
| **Aransas Pass Texas(USA)** | 1977 | - | 4,8 | - | - | Shane (1980) in Shane *et al.* (1986) |
| **Florida Gulf** | 1977 | - | - | - | - | |
| panhandle | | - | 0,12 | - | - | Odell & Reynolds (1980) in Chapmand & Feldhamer (1982) |
| peninsula | | - | 0,06 | - | - | Odell & Reynolds (1980) in Chapmand & Feldhamer (1982) |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Charlotte Harbour to Crystal river Florida (USA)** | * 1980 | - | 0,07 | - | - | Odell & Reynolds (1980) in Shane *et al.* (1986) |
| **Charlotte Harbour Florida (USA)** | 1980 | - | 0,17 | - | - | Thompson (1981) in Shane *et al.* (1986) |
| | 1981 | - | 0,2 | - | - | Thompson (1981) in Shane *et al.* (1986) |
| **Indian and Banana river Florida (USA)** | 1980 | - | 1,22 | - | - | Letherwood & Show (1980) in Chapmand & Feldhamer (1982) |
| | 1979 | - | 0,89 | - | - | Letherwood & Show (1980) in Chapmand & Feldhamer (1982) |
| | 1977 | - | 0,52 | - | - | Letherwood (1979) in Chapmand & Feldhamer (1982) |
| **Sarasota Florida (USA)** | * 1978 | - | 0,6-1,8 | - | - | Wells (1978) in Shane *et al.* (1986) |
| **PACIFIC** | | | | | | |
| **California Coastal (USA)** | 1958-1989 | 234 (95%CI) 205-263 to 285 265-306 | - | stable during 11 years | - | NOAA (2006) |
| **San Diego California (USA)** | 1984-1989 | 234-285 | - | - | Little evidence for long-term site fidelity | Defran & Weller (1999) |
| **Natal (south-east of southern Africa)** | 1999 | 900 | 2,25 | - | - | Wells & Scott (1999) |
| **Hawaii** | 2002 | 2.046 | - | - | - | NOAA (2006) |
| **Maui and Lana'I Hawaii** | 2001 | 122 | - | - | - | Baird *et al.* (2001) |
| | 1996-1998 | 365 (95%CI306-437) | - | - | - | NOAA (2006) |
| | 1999-2000 | 186 (CV=0,12) | - | - | - | NOAA (2006) |
| **Southern California (USA)** | 1991-1994 | 78 (95%CI 60-102) to 271 (240-306) | - | - | - | Carretta *et al. (*1998) |
| **California-Oregon-Washington Offshore (USA)** | 1991-1996 | 956 (CV=0,14) | - | - | - | Forney *et al.* (2000) |
| | 1996-2001 | 3.053 | - | - | - | NOAA (2006) |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Amakusa western Kyushu, Japan** | 1995-1997 | 218 (CV=5,41%) | - | - | - | Shirakihara *et al.* (2002) |
| **MEDITERRANEAN** | | | | | | |
| **Alboran sea (Spain)** | 2000-2003 | 584 95%CI 278-744 | 0,04 | Decreasing | - | Cañadas & Hammond (in press) in Reeves & di Sciara (2006) |
| **Almeria (Spain)** | 2001-2003 | 279 95%CI 146-461 | 0,06 | Decreasing | - | Cañadas & Hammond (in press) in Reeves & di Sciara (2006) |
| **Asinara island National Park (Italy)** | 2001 | 22 95%CI 22-27 | 0,05 | Decreasing | - | Lauriano *et al.* (2003) in Reeves & di Sciara (2006) |
| **Balearic Islands & Catalonia (Spain)** | 2002 | 7.654 95%CI 1.608-15.766 | 0,08 | Decreasing | - | Forcada *et al.* (2004) in Reeves & di Sciara (2006) |
| **Balearic Islands (Spain)** | 2002 | 1.030 95%CI 415-1.849 | 0,08 | Decreasing | - | Forcada *et al.* (2004) in Reeves & di Sciara (2006) |
| **Gulf of Vera (Spain)** | 2003-2005 | 256 95%CI 188-592 | 0,04 | Decreasing | - | Cañadas (unpublished) in Reeves & di Sciara (2006) |
| **Valencia (Spain)** | 2001-2003 | 1.333 95%CI 739-2.407 | 0,04 | Decreasing | - | Gomez de Segura *et al.* (in press) in Reeves & di Sciara (2006) |
| **North Adriatic Sea (Gulf of Trieste, Slovenia)** | 2002-2004 | 47 | 0,08 | Decline 50% the past 50 years | - | Bearzi *et al.* (2004) |
| **Strait of Gibraltar** | 2005 | 258 95%CI 226-316 | 0,51 | - | - | de Stephanis *et al.* (2005) in Reeves & di Sciara (2006) |
| **Amvrakikos Gulf (Greece)** | 2001-2005 | 152 95%CI 136-186 | 0,38 | - | - | Reeves & di Sciara (2006) |
| **North-eastern Adriatic sea (Kvarneric, Croatia)** | 1990-2004 | 120 | - | Decline 50% the past 50 years | - | Reeves & di Sciara (2006) |
| **Alboran sea and Murcia (Spain)** | 2004-2005 | - | 0,07 | Decreasing | - | Cañadas (unpublished) in Reeves & di Sciara (2006) |
| **Lampedusa island (Italy)** | 1996-2000 | 140 | - | - | - | Reeves & di Sciara (2006) |
| **Ionian Sea (Greece)** | 1993-2003 | 48 | - | - | - | Reeves & di Sciara (2006) |
| **Central Adriatic Sea (Kornati & Murtar sea, Croatia)** | 2002 | 14 | - | - | - | Reeves & di Sciara (2006) |
| **Tunisian waters** | 2001-2003 | - | 0,19 | - | - | Ben Naceur *et al.* (2004) in Reeves & di Sciara (2006) |

| | | | | | | |
|---|---|---|---|---|---|---|
| **BLACK SEA** | | | | Declining until 1983. increasing 1993-2005, declining 2006 | | Reeves & di Sciara (2006) |
| **Turkish Straits System (Bosphorus, Marmara Sea and Dardanelles)** | 1997 | 495 95%CI 203-1,197 | - | | - | Dede (1999), cited after: IWC (2004) in Reeves & di Sciara (2006) |
| | 1998 | 468 95%CI 184-1,186 | - | | - | Dede (1999), cited after: IWC (2004) in Reeves & di Sciara (2006) |
| **Kerch Strait** | 2001 | 76 95%CI 30-192 | - | | - | Birkun *et al.* (2002) in Reeves & di Sciara (2006) |
| | 2002 | 88 95%CI 31-243 | - | | - | Birkun *et al.* (2003) in Reeves & di Sciara (2006) |
| | 2003 | 127 95%CI 67-238 | - | | - | Birkun *et al.* (2004) in Reeves & di Sciara (2006) |
| **NE shelf area of the Black Sea** | 2002 | 823 95%CI 329-2,057 | - | | - | Birkun *et al.* (2003) in Reeves & di Sciara (2006) |
| **NW, N and NE Black Sea within Ukrainian and Russian waters** | 2003 | 4.193 95%CI 2.527-6.956 | - | | - | Birkun *et al.* (2004) in Reeves & di Sciara (2006) |

## 2.2. Studied Area

Cardigan Bay is located in West Wales, UK (Figure 3). Cardigan Bay Special Area of Conservation (SAC) is situated off south Ceredigion and north Pembrokeshire in the southern part of Cardigan Bay. The landward boundary runs along the coast, from Aberarth to just south of the Teifi Estuary at the following coordinates (expressed as decimal degrees): South Lat: 52.0783 Long: 4.7650, West Lat: 52. 2186 Long: 5.0042, North Lat: 52.4300 Long: 4.3967, East Lat: 52.2500 Long: 4.2333 (Baines, *et al.,* 2002; Figure 3). The site extends approximately twelve miles offshore, with an area of 1039 $km^2$ subdivided in 517 $km^2$ inshore and 522 $km^2$ offshore.

Cardigan Bay's topography is characterized by high cliffs, small coves and a few larger sandy beaches. The Teifi is by far the largest river to flow into the bay. The middle and northern sections of the Cardigan Bay coast have generally a low-lying topography while the north-western part of the Bay is cliff-bound and rugged, with small coves and offshore islands. The Bay is a shallow basin comprising a mixture of sediments which tend to grade from gravel and cobbles offshore to a finer sand and silt nearshore, although patches of cobble and boulder occur all along the coast. The distribution of sea bed sediments is largely dependent upon tidal current strength; gravels occur where the currents are strongest, and muds where they are weakest (Baines, *et al.,* 2000). The water depth in the bay does not exceed 50m and becomes increasingly shallow from west to east, with an average depth of approximately 40m (Evans, 1995).

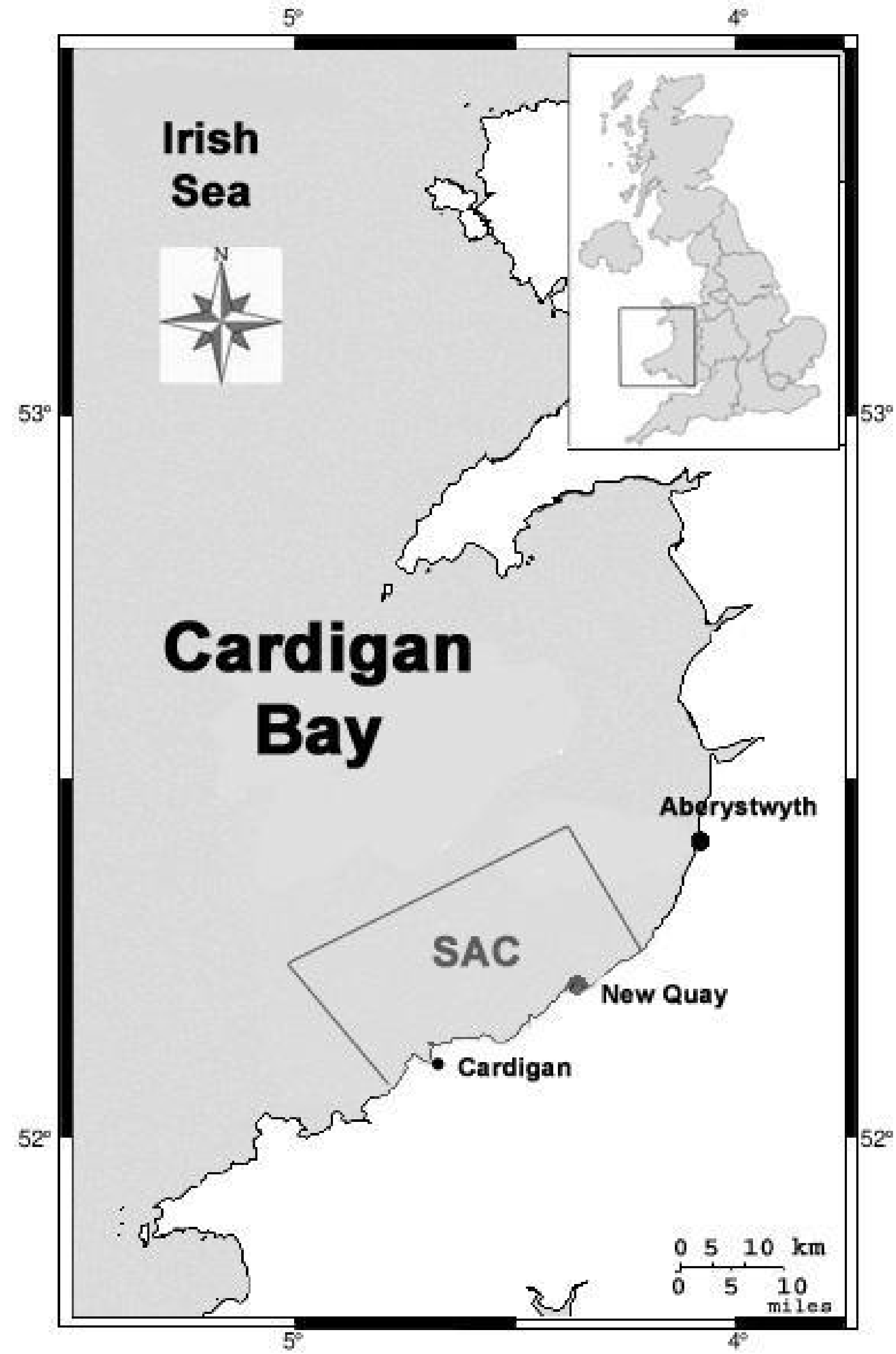


**Figure 3:** Cardigan Bay (SAC) in UK.

Cardigan Bay and the Irish Sea are important marine areas. Warm waters from the North Atlantic Drift meet cooler, tidally driven waters at both the northern and southern ends of the Irish Sea. This produces nutrient upwelling that provide suitable conditions for plankton concentrations to develop, and upon which abundant fish, seabirds, seals and cetaceans feed. The waters are often relatively calm, being protected from the Atlantic by the country of Ireland (Evans, 1995).

### 2.3. Photo-identification (Photo-ID)

To study the distribution, abundance and dynamics of an animal population, it is essential to be able to recognise and follow individuals within a population through time. Cetaceans are only visible for a brief moment, which makes the study of these animals quite complicated. With the development of photo-ID techniques, scientists are able to do this without unduly disturbing the animals.

The photo-ID technique consists of the identification of individuals using photographs of natural markings. Recognition of individual bottlenose dolphins is based almost entirely on the shape of the dorsal fin, scars that are permanent marks, (e.g. missing pieces from the trailing edges of the dorsal fins or nicks), pigmented areas, and a range of scratches and skin bruises (Figure 4). This technique was first used in bottlenose dolphin identification in the 1970’s (Würsig & Würsig, 1977).

**Figure 4:** First photo showing nicks. Second photo showing pigmented area. Third photo showing scratches and skin bruises.

The method of photo-identification is based on the assumptions that the species are correctly identified. In mark-recapture studies, the two main types of mistakes are called false positives and false negatives. False positives occur when two photos of two different individuals are erroneously matched as the same individual, leading to underestimation errors in population estimates, especially for large populations of less easily identifiable species. False negatives happen when two sightings of the same individual do not get matched and are marked as different individuals (Gunnlaugsson & Sigurjónsson, 1990; Stevick, *et al.*, 2001), and therefore, overestimate the population size. Errors can be caused by poor quality photographs, less than ideal observation conditions, and the heterogeneity of samples due to the lack of distinctiveness or permanence of the markings (Stevick, *et al.,* 2001).

Heterogeneity of samples and distinctiveness of marks can have serious effects on population abundance estimations. Wells & Scott (1990) used two mark-recapture techniques to estimate population size of bottlenose dolphins in Florida, and found that both Petersen (also called the Lincoln index) and Schnabel methods underestimated the known population size, but that the Schnabel method was less biased. They argued that the bias was probably caused by the heterogeneity of sightings, as varying ages and sex condition were shown to have different sightings probabilities.

However, not all these errors can be eliminated, and the resulting decrease in sample size will adversely affect the precision of the population abundance estimate (Stevick, *et al.,* 2001).

### 2.4. Mark Recapture

Mark recapture studies are a powerful tool for conservation managers, and can be used in any situation where animals can be marked (or otherwise identified) and detected later by capture or sighting. An important distinction can be made between open and closed populations in mark recapture studies. A closed population remains constant in size and composition during the study, while an open population is subject to animal births, deaths, or migrations. Although all populations are subject to these processes, it is possible effectively to have closure by doing the study over a short time, and this is often desired. In order to apply closed population models with confidence, the following assumptions need to be fulfilled:

(i) a marked animal will be recognized if recaptured

(ii) marked animals have the same probability of being recaptured as unmarked animals,

(iii) marks are not lost,

(iv) within a sample, all the individuals have the same probability of being captured

(Hammond, P.S. 1990; Campbell *et al.*, 2002; Shirakihara *et al.,* 2002; Chilvers & Corkeron, 2003; Irwin & Würsig, 2004).

# 3. PROBLEM and JUSTIFICATION

## 3.1. Problem

The current status of Cardigan Bay bottlenose dolphin population does not have yet to be fully assessed, nor has it been evaluated how Cardigan Bay bottlenose dolphin population size has responded to the conservation strategies and an implemented management plan.

## 3.2. Justification

Cardigan Bay is one of the very few areas around the UK, as Moray Firth, where significant numbers of bottlenose dolphin are known to occur regularly (Ceredigion County Council *et al.,* 2001). This is why the bottlenose dolphin Cardigan Bay population has been protected since 2001 with conservation strategies and a management plan implemented after its proposal as a Special Area of Conservation (SAC). The management plan indicated two important attributes to be monitored in the bottlenose dolphins: annual abundance (Taylor & Gerrodette, 1993), and spatial distribution within the SAC (Ceredigion County Council *et al.,* 2003). It was not until 2004 that this area was formally designated an SAC under the European Union’s Habitats Directive parameters, in order to maintain the bottlenose dolphin population at favorable conservation status.

# 4. AIMS

## 4.1. General Aim

To observe the trend in the bottlenose dolphin population size in Cardigan Bay (SAC).

## 4.2. Specific Aims

- To estimate the population size during a period of three years 2003, 2004 and 2005.

- To compare the population size obtained in this period (2003 to 2005) with information collected in the past, in order to establish a trend.

# 5. MATERIALS and METHODS

## 5.1. Survey Design

### 5.1.1. Survey Population

The survey population was that of the Cardigan Bay (SAC) bottlenose dolphin *(Tursiops truncatus*).

### 5.1.2. Survey Variables

The independent variable was time, and the dependent variables were population size and trend.

## 5.2 Method

This study comprised a combination of data obtained by the use of line-transect and Photo-ID methodology (photos were analyzed using Adobe Photoshop software and Fax Viewer) and the mark-recapture method. With the mark-recapture method, the first time an individual is sighted in the year of survey, it is marked, and every time it is sighted again, it is considered as recaptured. To meet assumptions of the mark-recapture method (mentioned above), the following parameters were considered: For assumption one, out of focus, or poor quality photographs were discarded, and the identification was confirmed by a second observer. The second assumption is met because photo-ID does not involve physical interaction (Wilson *et al.*, 1999). The third assumption is easily met because permanent marks were used, but the fourth assumption can be violated if it is assumed that all the animals behave in the same way. Since individual differences in surfacing rate and boat avoidance behaviour affect the probability of obtaining a usable photograph (Hammond, 1986; termed heterogeneity of capture probability), it was necessary to use a model that can relax this assumption; otherwise it would result in an underestimation of population size.

Since allow heterogeneity of capture probabilities and this is problematic in open population models, close model were use (Wilson *et al.,* 1999). Population closure is only a reasonable assumption when experiments are of relatively short duration. The data were analyzed through CAPTURE application of program MARK v.4.1 (Mark and Recapture Survival Rate Estimation), developed by the Department of Fisheries and Wildlife, Colorado State University (2004). This application has 11 available models that test for three sources of variation in sightings probabilities; that of (i) the heterogeneity response ($M_h$), assumes that each animal has its own unique capture probability, which remains constant over all the sampling times (ii) the trap response or behavioural response ($M_b$), where the animal may become either 'trap happy' or 'trap shy' after their first capture and (iii) the time variation or Schnabel Model ($M_t$), assumes that every animal in the population has the same probability of capture at each sampling time. The 11 models were all based on these principles and/or combinations of the three (for example, $M_{bh}$, $M_{th}$, $M_{tb}$), plus one additional model where probability of capture remains constant ($M_0$).

In this study, the models used were selected purely on biological grounds. The time heterogeneity model ($M_{th}$) (Chao *et al*. 1992), in which the assumptions of heterogeneity and time were relaxed, was applied. Chao *et al.* (1999) have derived a nonparametric estimator for abundance for the model ($M_{th}$) using the idea of sample coverage (defined as the relative fraction of the total individual capture probabilities of the capture animals) and an expression for its asymptotic variance from an expanded Taylor series (Wilson *et al.,* 1999).

Conversely, however, both the null model ($M_0$) and the behavioural models ($M_b$) were largely ignored, the reasons being that the null model is unlikely to occur under natural circumstances, and as photo-identification uses existing marks, it involves no physical interaction between the animals and the researcher in relation to the marking event, and so behavioural responses of this type cannot occur, so the behavioural models were simply not applicable to the study (Wilson *et al.,* 1999).

## 5.3. Data Collection

Data were collected during boat surveys within Cardigan Bay SAC during 2003, 2004 and 2005, as part of Sea Watch Foundation's research on bottlenose dolphins. The surveys were conducted either aboard the MV *Sulaire*, that is a 10m charter vessel, or, in 2005, the MV *Dunbar Castle*. MV *Sulaire* was equipped with a Global Positioning System (GPS), a Shipmate RS 5700, as well as a semi-displacement hull and 380hp turbo diesel engine. The observational platform was 3m above sea level having a viewing angle of 360°, although observers mainly concentrated on 180° from each side and ahead of the boat. The surveys were carried out between April and November, which were months with best weather, light, wind and sea conditions, in Beaufort sea state of 0 - 3 during good light conditions, to make the sightings more reliable (Barco, *et al.,* 1999). When the sighting conditions were good, i.e. sea state 2 or less, low swell, and no precipitation or fog, the photo-identification surveys were combined with distance-sampling surveys for bottlenose dolphins, harbour porpoise (*Phocoena phocoena*) and Atlantic grey seals (*Halichoerus grypus*). The boat surveys were conducted following predefined transect routes to cover the area uniformly (Figure 5). Each transect was conducted at a speed of 8 knots (14 km per hour). Since this is twice the average travel speed of dolphins, it reduces the probability of meeting the same individuals, and thus them being counted more than once.

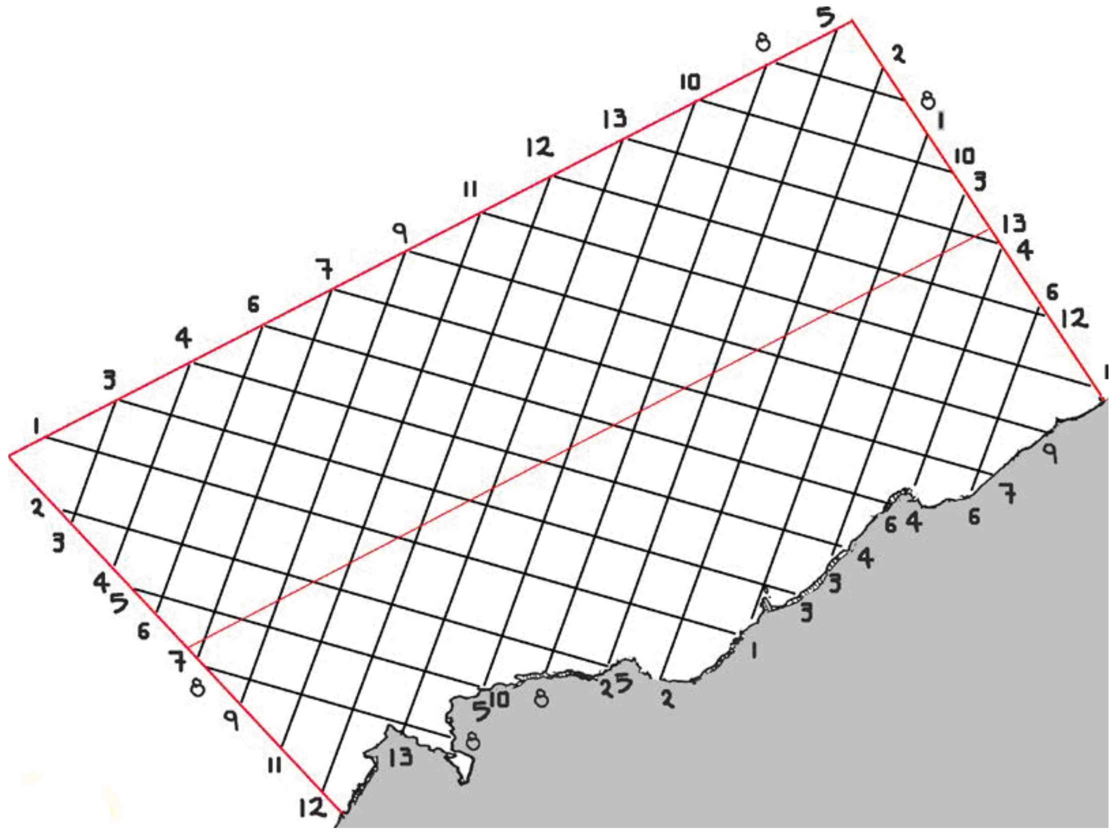

**Figure 5:** Predefined transects in Cardigan Bay SAC.

A ***Sightings Form*** (Annex 2) was also completed to log bottlenose dolphin reactions to the boat, dolphin behaviour, all recorded GPS positions, and both distance and angle estimates. The time and the location were recorded once dolphins were sighted. To be photographed, the vessel may need to approach the dolphins, whereupon the transect was abandoned. An encounter was defined as the period spent photographing a dolphin group. During encounter time, pictures were taken with a Canon D60 digital camera with 75-300mm zoom lens (f 4.0 – 5.6). The main objective of each encounter was to take the highest possible number of clear images from both sides of each individual. So in an ***Encounter Sheet*** (Annex 3), encounter length and number of encounters, and a log of picture frames taken were all recorded. A spacer picture was taken at the start and end of each encounter.

Encounters were continued until all the members of the group had been photographed or the contact had been lost. If signs of avoidance were shown, or after approximately ten minutes without a sighting, the survey leader had to decide whether to go back for tracking or continuing the line transect survey using Distance.

**5.4. Data Analysis**

5.4.1. Individual Recognition from Identification Pictures.

Fin morphologies of individuals were identified from photographs of their dorsal fin. Markings that occur naturally, like skin pigmentation, fin notches, tears, deformities, tooth rakes and skin bruises on their dorsal fin and flanks, were examined with emphasis on marks that persist throughout the study period. The majority of the features were used to confirm matches, reducing the possibility of false positives (Scott, *et al.,* 1990; Würsig, & Jefferson, 1990). Using a light box and 8x magnifier glass, transparencies were analyzed whilst downloaded digital pictures were examined using Adobe Photoshop software and Fax Viewer.

A ***Film Sheet*** (Annex 4) was completed for the slides, and an Excel spreadsheet for the digital pictures. For each picture a quality grade (scored 1-4), was assigned, based on image size, focus, lighting, angle of fin and exposure. For example, a photograph that had the subject full frame, in sharp focus and at a good angle was recorded as 1, whereas, a photograph in which only a part of the fin was visible was recorded as 4. Photographs with insufficient data or of poor quality were discarded.

Each match was identified and then subjected to a similar independent analysis by a second observer, thus avoiding bias and reducing the possibility of identifying false positives and false negatives. Profiles for both right and left flanks of each animal were selected from the best images to be catalogued. Finally, an encounter number was assigned, where a unique number was given to each new studied animal.

### 5.4.2. Data Analysis for Population Size

Using the FORTRAN program MARK v.4.1, population estimates were made, based on the number of marked individuals. In order to analyze the encounter histories for the marked animals selected in this program, data were transcribed into binary form, where the number '1' indicated that an animal had been sighted, and '0' indicated that the animal had not been sighted.

The total population size was estimated from the proportion of marked animals. The proportion of marked animals in each encounter was calculated by taking the number of dolphins seen, and subsequently counting the number of marked animals present in the encounter. The proportion of marked dolphins per year was calculated as the average for all encounters. For each surveyed year, the marked individual proportion was 0.71 in 2003, 0.62 in 2004 and 0.51 in 2005. The population estimates derived by MARK of $\boldsymbol{M_{th}}$ model were recalculated and adjusted with the proportion of unmarked individuals using the following equation (Wilson *et al.,* 1999):

$$\hat{N}_{Total} = \frac{\hat{N}}{\hat{\theta}}$$

where $\hat{N}_{Total}$ = total population size, $\hat{N}$ = mark-recapture estimates of population size, and $\hat{\theta}$ = proportion of animals with marks in the population.

A Kruskal-Wallis test was used to test for significant differences in population size between the three years of study. To make this calculation, a total of three values of population size were obtained per year, calculating the population size in the three main months of the years (July, August and September); a Kruskal-Wallis test was applied comparing the months, so as to be sure that no effect of time existed in the population size estimate.

A population trend was more difficult to calculate, due to the short time of study (three years), given that Wilson *et al.* (1999), found that more than eight years data collection was needed to detect a significant (at the 10%

probability level) trend in population size, given that dolphins are long-lived animals. For this reason, the intrinsic population growth rate (**R**) was calculated, as it gives us an indication of the trend of the population. The growth rate for this study was estimated between years as:

$$R = \frac{Nt + 1}{Nt}$$

where *N* is the population size at a given time (Akcakaya *et al.,* 1999).

To make an approximation of the population trend, available data from other studies of population size collected for the same population were used. R was calculated for those data in the same way, and all the estimates for R (this study and others) were used to calculate the trend for the population.

### 5.4.3. Residency Patterns

The percentage of marked individuals seen during one, two or three consecutive years gives the residency pattern. According to the capture frequency, the individuals were catalogued as: frequent seen 12 or more times through the study period; common seen 8 to 11 times; occasional seen 4 to 7 times; and rare seen on 3 or less times (following Culloch, 2004).

## 6. RESULTS and DISCUSSION

### 6.1. Results

The survey effort decreased with survey time, due to logistic conditions, and the encounters decreased proportionally with number of survey days (Table 2).

A total of 46 transect legs were covered in 2003 (507 Km), 48 legs in 2004 (653 km) and 92 transect legs in 2005 (1490) of a total of 30 transect legs.

**Table 2:** Effort survey. The months of each year were the survey period for the line transect method. The number of days and trips made each year, number of hours dedicated to the survey, number of encounters, number of hours spent in encounters, and surveyed distance are observed in the columns.

| Year | Months | Survey Days | Survey Trips | S. Hour Effort | Encounters | Ecou. Hours | Distance |
|---|---|---|---|---|---|---|---|
| 2003 | May-Sept | 74 | 74 | 328 | 139 | 17.05 | 507 Km |
| 2004 | May-Sept | 59 | 59 | 263 | 121 | 26.3 | 653 Km |
| 2005 | April-Nov | 33 | 33 | 209 | 66 | 21.11 | 1490 Km |
| **TOTAL** | | **166** | **166** | **800** | **326** | **64.46** | **2650 Km** |

A total of 121 different individuals were photographer (well marked plus individuals photographed just in the right side of the fin) in 2003; 108 in 2004 and 154 in 2005.

The mark-recapture analysis suggested an average population size of 178 +/- 22 individuals. The results showed an increasing tendency in the intrinsic population growth rate (**R**) between years (Table 3). Nevertheless no significant differences were found in the population size estimates through years (Kruskal-Wallis test, $H_{2,\ N=3} = 2.0$; $p = 0.36$, Figure 6); and no effect of time in the population size estimate was found (Kruskal-Wallis test, $p = 0.22$).

**Table 3:** Estimation of population size, using Chao ($M_{th}$) model, where $\hat{N}$ is the population size using marked animals, $\hat{\theta}$ is the proportion of marked animals, $\hat{N}_{Total}$ is the total population size, SE is the standard error of the $\hat{N}$ population, CI are the confidence intervals of $\hat{N}$ population, P is the capture probability, and R is the intrinsic population growth between two consecutive years.

| YEAR | $\hat{N}$ | $\hat{\theta}$ | $\hat{N}_{Total}$ | SE | CI (95%) | P | Years | R |
|---|---|---|---|---|---|---|---|---|
| 2003 | 103 | 0.71 | **145** | 10 | 99 - 115 | 0.11 | | |
| 2004 | 100 | 0.62 | **161** | 16 | 91 - 123 | 0.07 | 2003-2004 | 1.11 |
| 2005 | 116 | 0.51 | **227** | 40 | 91 - 167 | 0.06 | 2004-2005 | 1.14 |
| **TOTAL** | | | | | | | 2003-2005 | 1.15 |

Three years is not enough time to see a trend in the population size for a long-lived animal like the bottlenose dolphin and cetaceans in general. A growing population tendency of 46.4% was observed in 16 years (1989 to 2005) when analyzing data collected from different studies, but this is a dangerous comparison since the estimates pre-2000 involved very different spatial coverage and levels of effort. And the realistic comparison can be made since 2001.

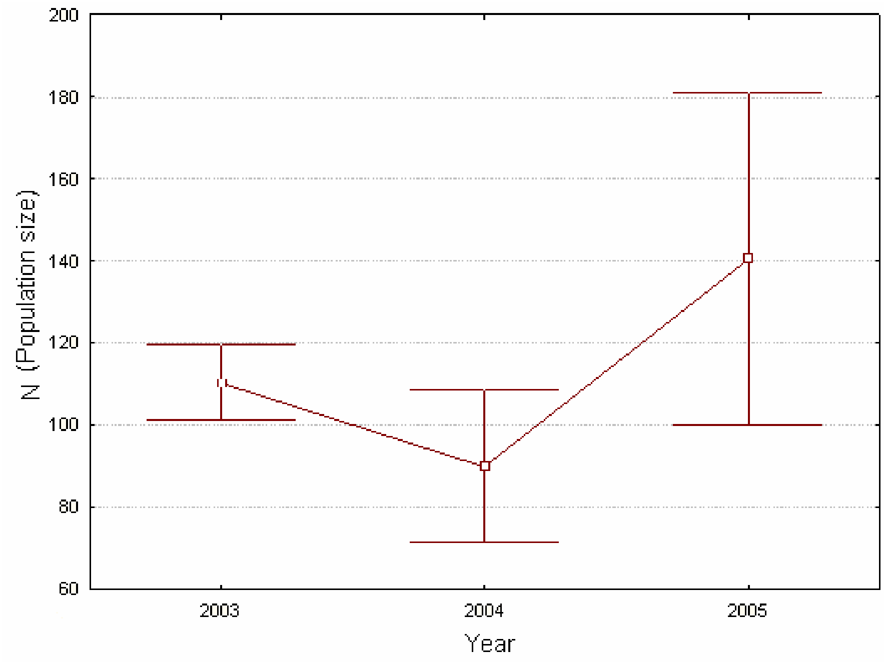


**Figure 6:** Kruskal-Wallis results for the comparison between years.

The full set of results obtained by the program MARK for the population estimations of the marked animals, for each year using Chao time-heterogeneity dependency model ($M_{th}$); are shown in annex 5.

The discovery curve (Figure 7) has yet to reach an asymptote.

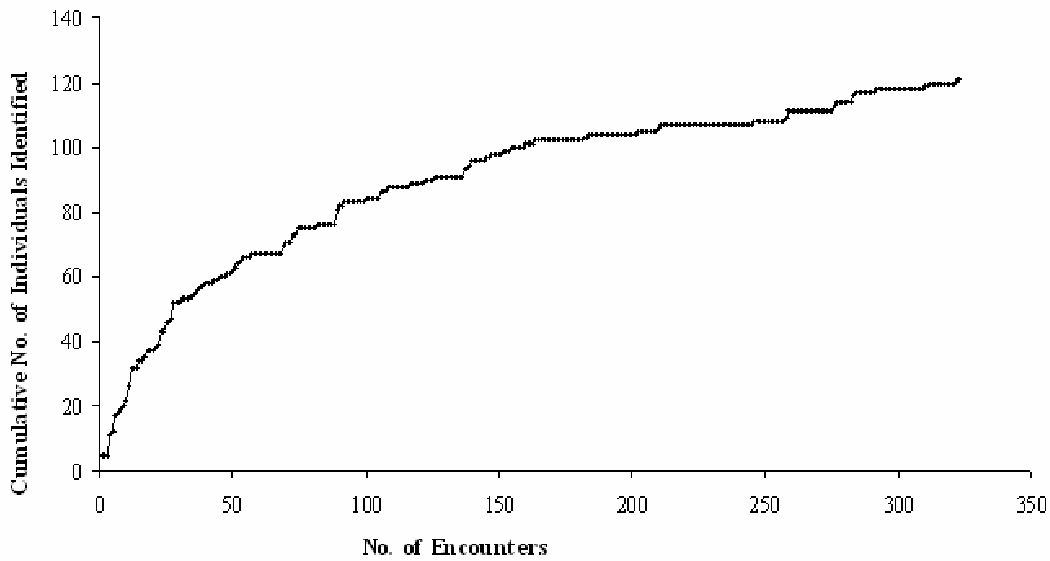


**Figure 7:** Discovery curve of cumulative number of individuals identified throughout number of encounters.

Photo identification and distance sampling are both commonly used techniques to monitor marine mammal populations, but rarely are both used on the same population, the two techniques could be used in synchrony on bottlenose dolphins, using abundance estimates derived from distance sampling and photo ID (Felce *et. al.*, 2006), the following abundance estimates were obtained in 2005 (Figure 8):

- **150** (80-280) using Distance 4.1
- **227** using Mark Recapture
- **175** based on the average proportion of well-marked individuals.

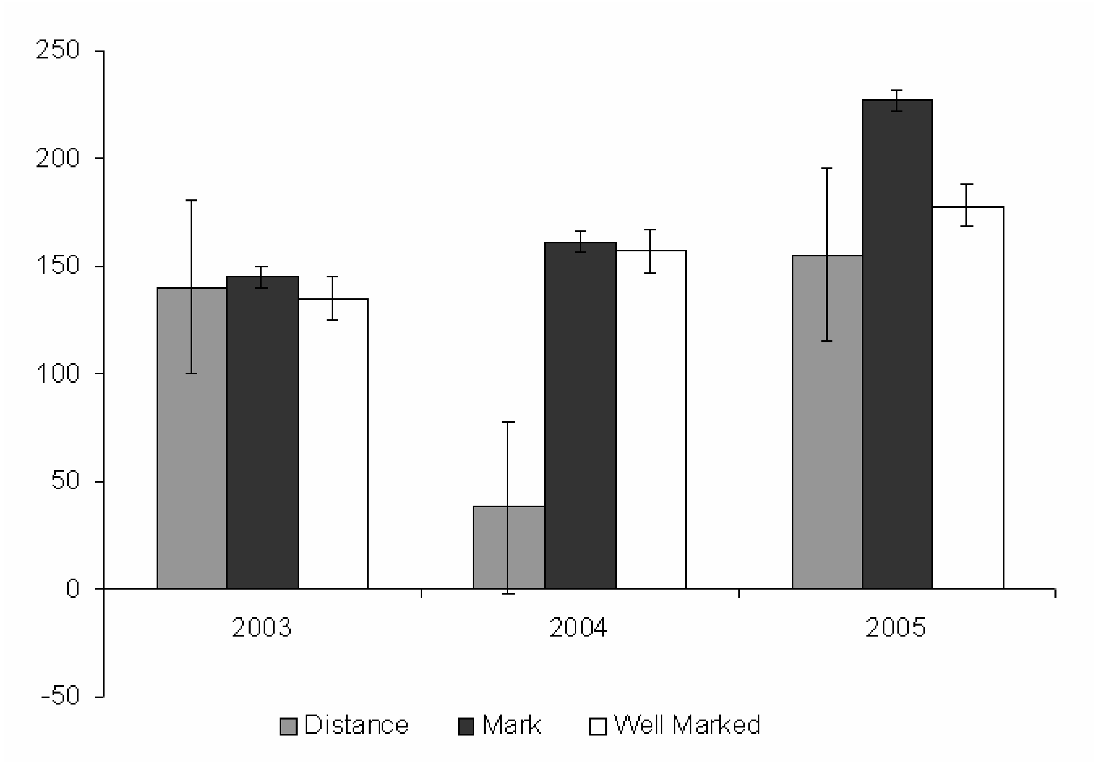


**Figure 8:** Abundance estimates derived between 2003 and 2005, using different techniques, Distance, Mark-recapture (photo ID), and based on the average proportion of well-marked individuals.

This population showed a high residency pattern, since 71% of the marked individuals were seen in two or three consecutive years (Figure 9). 51 individuals (the 42.1% of the total marked individuals recorded) were catalogued as frequent and common, while 31 dolphins (25.6%) were occasional, and 39 individuals (32.2%) were rare (Figure 10). A high capture frequency (representing the times that one animal was seen during the study period), was obtained, ranging from 1 to 33 times. This confirmed the high site fidelity within the population.

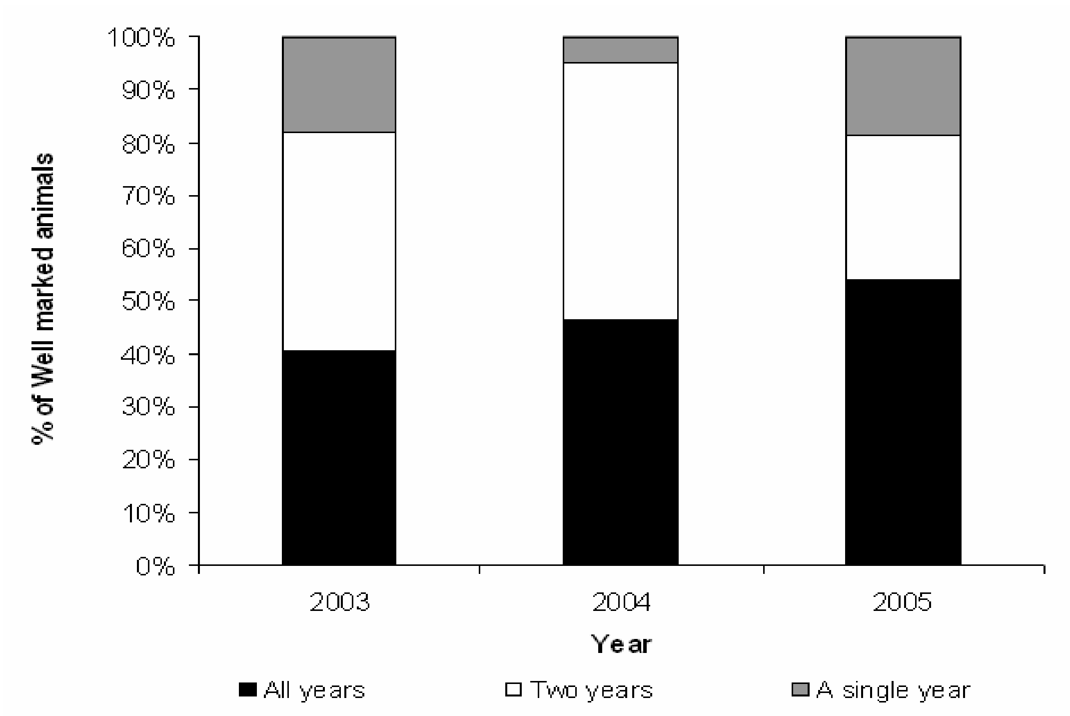


**Figure 9:** Percentage of marked animals seen during one year (28%), two years (40%) and three consecutive years (31%).

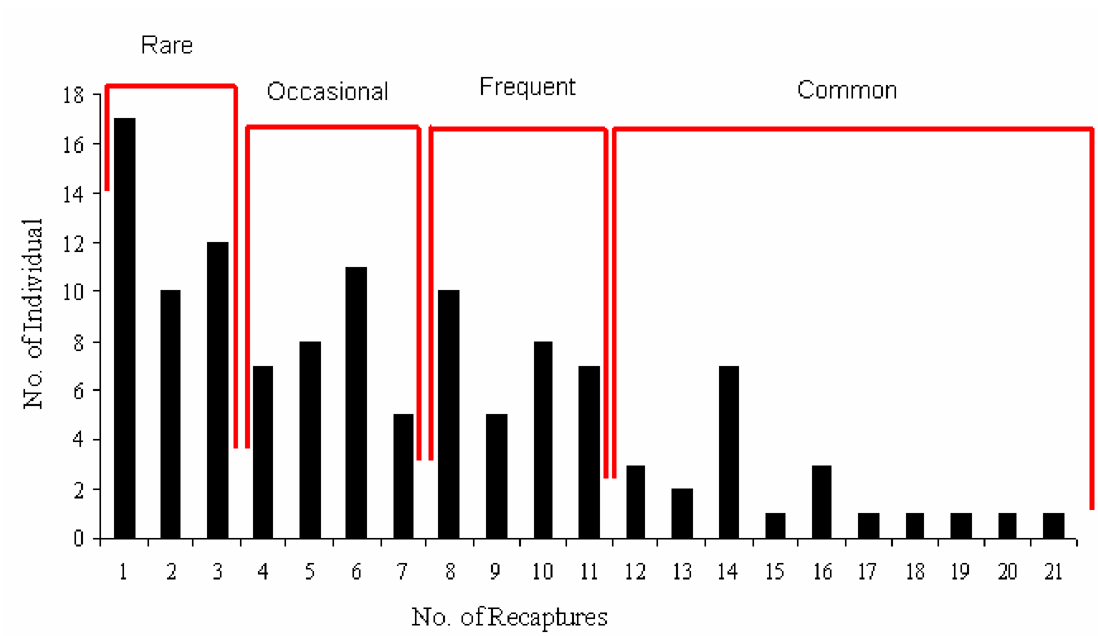


**Figure 10:** Histogram showing the distribution of recapture frequencies for all marked bottlenoses identified in the present study during 2003 to 2005.

## 6.2. Discussion

The Cardigan Bay bottlenose dolphin population seems to be small when compared with the size of other coastal and offshore populations recorded (Table 1), but for the area of study it is one of the larger ones in North West Europe (Evans personal communication, 2006). Habitats in shallow waters and protected from open oceans; as is the case for Cardigan Bay, may attract small populations of bottlenose dolphin (Wells *et al*., 1997). However, the Cardigan Bay population was higher than some other critically smaller coastal populations, which did not reach the 100 individuals, such as those at Moray Firth (Scotland), Western Galveston Bay (US), Asinara Island National Park (Italy), Central Adriatic Sea (Kornati & Murtar Sea, Croatia), North Adriatic Sea (Gulf of Trieste, Slovenia), Ionian Sea (Greece), and Kerch Strait (Table 1). According to some population viability analyses of bottlenose dolphins, populations of less than 100 individuals will face high extinction probabilities (Thompson *et al.*, 2000).The average Cardigan Bay population size in the three years of study (178 individuals) was 7% higher than that of other coastal populations (166, Table 1). However, it is much smaller than oceanic populations, which can reach the 9.912 individuals (Eastern Gulf of Mexico, Table 1). However, population size is a parameter very hard to compare directly in space and time, due to the range in size of sampling area surveyed in different studies. For this reason, we consider density as a better source of comparison between populations. The density value found in Cardigan Bay (0.18 indivs/ $km^2$) was low when compared with the average density of 0.51 indivs/ $km^2$ registered in other areas (Table 1). When compared with density values for coastal areas (with an average of 0.22 indivs/ $km^2$), Cardigan Bay population density was 18% lower. Nevertheless, there are places with even lower bottlenose dolphin density registered, such as the Alboran Sea, Gulf of Vera, and Valencia in the Mediterranean Sea, with 0.04 indivs/ $km^2$ (Table 1), in contrast to Aransas Pass, Texas in the North-West Atlantic, with the highest density values registered (4.8 indivs/ $km^2$; Table 1). Cardigan Bay presented a population abundance estimate slightly higher than the average, but with a lower density, compared with other studies.

According to our results and comparisons, while the Cardigan Bay bottlenose dolphin population seems to be stable in the short term (three years), a tendency for a growing population seems to be the pattern. The size of this population was 125 individuals in 1993, a number that is generally acknowledged by Ceredigion Country Council *et al.,* (2001) to be small and vulnerable to impacts, reducing the ability to sustain itself. However, in 2005 we obtained an abundance estimate of 227 individuals, a number rather higher than the one obtained in the 2001 (Baines *et al,* 2002), who observed a total of 215 individuals (Table 1), supporting this hypothesis of recent population growth.

Considering that Cardigan Bay's bottlenose dolphin population growth rate was 46.4% in a period of 16 years (2.9% per year), we can assume under similar conditions that the Cardigan bottlenose dolphin population could double in size in 34 years. This value is just the 13% lower than which Perrin & Reilly, (1984), Slooten & Lad, (1991), and Hare *et al.,* (2002) suggested as the doubling time for a dolphin population (39 years). However, more information would be necessary to verify this population trend, the good source of resources provided by the Bay, as well as its carrying capacity to support a growing population of bottlenose dolphin.

The population growth rate depends on births, deaths, and migration rates. Although there is insufficient information to identify which factor is most influencing the Cardigan Bay population, we consider that a good proportion of population growth is due to the increasing birth rate; since a significant number of calves were observed during the study (29.1% of the encounters had calves with an average of 1.39 calves per encounter). Additionally, the proportion of individuals seen only during a single year of sampling (28%, Figure 3) suggested some immigration. Some of the factors that have probably allowed the increase in the dolphin population in this Bay may be a consequence of an appropriate effort to conserve the population, and to a decrease in mortality rates. Conservation strategies have been applied in the management plan of the SAC since 2001, which include: 1) a management control of any negative impacts on the dolphins as a result of changes in natural variables (salinity, sea temperature, fronts etc) influenced by humans activities, and 2) consideration of any land influences such as run-off, which carry polluted sediments and might have a negative effect on dolphin health and distribution (see Cardigan Bay Management Plan; Ceredigion Country Council *et al.,* 2001 for more details). Since disturbances cause fluctuation in population size (Akcakaya, 1999), future research needs to evaluate to what degree conservation strategies minimize human disturbance and may result in an increase in dolphin reproductive success and/or survival rate, and thus in population size.

The apparent success of bottlenose dolphins at Cardigan Bay contrasts with failures to increase the population size of marine mammals in other protected marine areas, which have aimed to protect different species. For example, dugong *(Dugong dugon)* populations of Nigaloo and Sark Bay Marine Parks in Australia are declining despite efforts to protect them. Preen (1998) suggests that these results can be explained by the low level of protection provided by some Marine Protected Areas (MPAs) where harmful activities, such as commercial fishing, seismic surveys, and oil and gas drilling, are permitted. This shows the importance of full conservation strategies where the population to conserve should be the priority, and all activities must be evaluated based on the impacts to these populations.

Another issue in current conservation strategies is the size of protected areas; since larger areas are needed for reserves to achieve benefits (Gerber *et al.,* 2003) such as a higher carrying capacity for dolphins and other populations. Most reserves are too small, representing only a small portion of the total range of species (Gell & Roberts, 2003), as in *Tursiops truncatus*. Cardigan Bay represents what is believed to be their main activity area in Wales (Ceredigion County Council *et al.,* 2001). This may be related according to Shane *et al.,* (1986) to a protected geographical area, predator absence, good food resources, and a low level of disturbance. As a consequence of these factors, the Cardigan Bay population shows high site fidelity. Comparing these results with the results obtained by Culloch (2004) for the Moray Firth, and having in mind that the Moray Firth population is considered a population with high site fidelity (Culloch, 2004 and Wilson *et al.,* 1999) the high site fidelity for Cardigan Bay population is confirmed, since 42.1% of the marked individuals were catalogued as frequent and common in Cardigan Bay and just 28.9% on the south side of the Moray Firth; 32.2% were rare in Cardigan Bay and 43.4% in the Moray Firth. Cardigan Bay fulfills all the characteristics of a population with site fidelity, which may contribute to the stability of this population in the Bay.

## 7. CONCLUSIONS

- No significant differences in the population size results were found between the three years of study.

- A growing tendency in the population size was found over a period of 5 years.

- High site fidelity of a portion of the dolphin population was found in Cardigan Bay.

- A longer time series data set is needed for more accurate results and understanding of the population.

# 8. RECOMMENDATIONS

It is important to carry out a monitoring program and collect accurate time series data of the population status. This study followed the methodology proposed by Baines *et al.,* (2002) which allowed temporal comparisons, covering the total Special Area of Conservation and using a simple confidence model for the characteristics of the population. In the long-term, an extension of this study will give more reliable results. This is why this methodology has been recommended for future research. It would be useful to address variables such as birth and death rates, migration rates, and trends in these vital parameters; to have a complete understanding of the population dynamics of dolphins in Cardigan Bay. A good comprehension of the ecosystem is also fundamental, as well as of resource availability to evaluate the ecosystem's carrying capacity, and up to what point the growth of the population is healthy and sustainable. Combine mark-recapture studies with line-transect surveys since they are providing complementary information.

It is recommended that conservation strategies are continued in order to maintain the population at favorable conservation status, and because the bottlenose dolphin population seems to be responding in a positive way to them.

Since little is known about the winter range of the Cardigan Bay dolphin population, it is important to address this issue to give the population complete protection over its full range, and if necessary, to consider the proposal of marine reserve networks.

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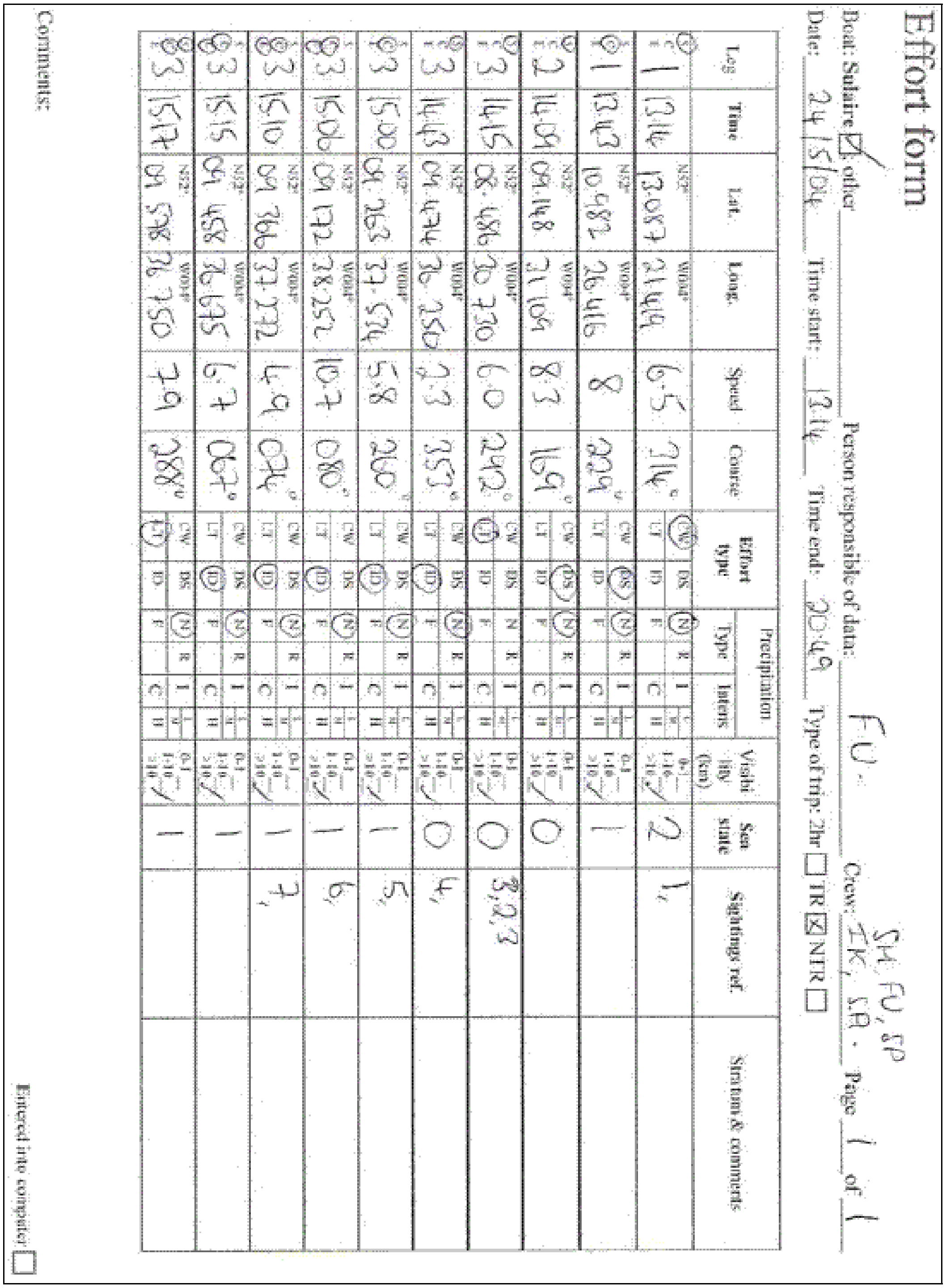
## 10. ANNEXES

**Annex 1:** Effort Form.



# Effort form

Boat: Sulaire ☑ other ______ Person responsible of data: FU. Crew: SH, FU, SP IK, SA. Page 1 of 1

Date: 24/5/04 Time start: 13.14 Time end: 20.49 Type of trip: 2hr ☐ TR ☒ NTR ☐

| Leg | Time | Lat. | Long. | Speed | Course | Effort type | Precipitation Type | Precipitation Intens | Visibility (km) | Sea state | Sightings ref. | Stratum & comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 13.14 | N52° 13.087 | W004° 21.419 | 6.5 | 314° | CW | N | | >10 | 2 | 1, | |
| 1 | 13.43 | N52° 10.982 | W004° 26.416 | 8 | 229° | DS | N | | >10 | 1 | | |
| 2 | 14.09 | N52° 09.148 | W004° 31.109 | 8.3 | 169° | DS | N | | >10 | 0 | | |
| 3 | 14.15 | N52° 08.486 | W004° 30.730 | 6.0 | 292° | LT | | | >10 | 0 | 3,2,3 | |
| 3 | 14.43 | N52° 09.474 | W004° 36.250 | 2.3 | 353° | ID | N | | >10 | 0 | 4, | |
| 3 | 15.00 | N52° 09.263 | W004° 37.574 | 5.8 | 260° | ID | N | | >10 | 1 | 5, | |
| 3 | 15.06 | N52° 09.172 | W004° 38.252 | 10.7 | 080° | ID | N | | >10 | 1 | 6, | |
| 3 | 15.10 | N52° 09.366 | W004° 37.272 | 4.9 | 074° | ID | N | | >10 | 1 | 7, | |
| 3 | 15.15 | N52° 09.458 | W004° 36.675 | 6.7 | 067° | ID | N | | >10 | 1 | | |
| 3 | 15.17 | N52° 09.578 | W004° 36.750 | 7.9 | 288° | LT | N | | >10 | 1 | | |

Comments:

Entered into computer ☐

**Annex 2:** Sighting Form

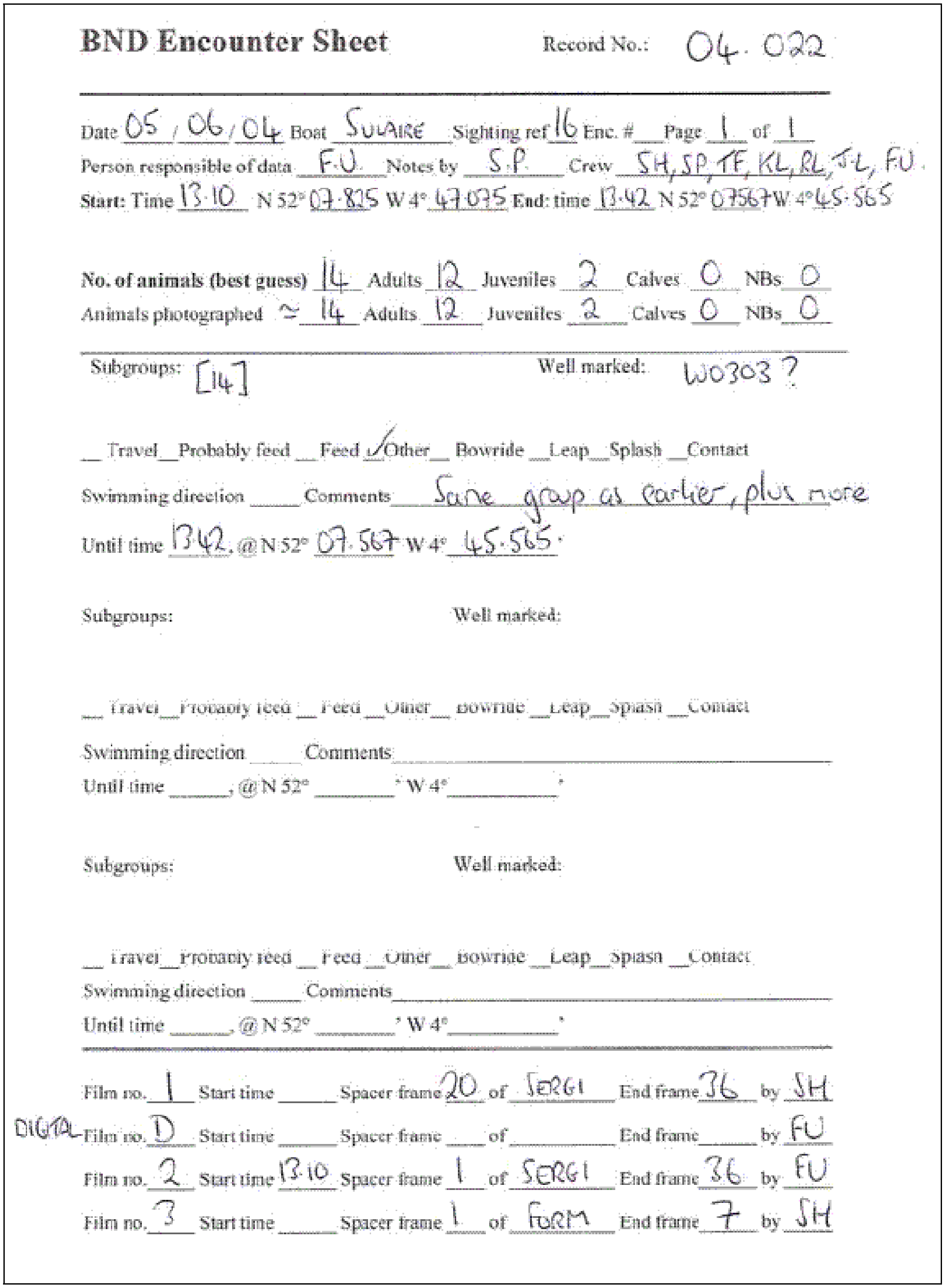
# Sightings form

Date: 24/05/04 Type of trip: 2hr _ TR✓ NT _ Page: 1 of 1

| | * Lat | * Long | * Dir | Distance Est. | Distance Ruler | * Species | * Total no. | A | J | C | NB | * Time | Effort type | Sea state | Beh Dir / Orient. | Reac. to Boat | Seen by |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| _1 | N52° 12.986 | W004° 22.623 | P-S 90 | 50m | | D HP S | 3 | 3 | | | | 1321 | CW DS LT ID | 2 | Hauled out | A T N | AM |
| _2 | N52° 09.666 | W004° 36.25 | P-S 50° | 300 | | D HP S | 3 | | | | | 1440 | CW DS LT ID | 1 | | A T N | FU SP |
| _3 | N52° 9.385 | W004° 36.948 | P-S 60° | 300 | | D HP S | 1 | | | | | 14.52 | CW DS LT ID | 1 | | A T N | F.U. |
| _4 | N52° 9.299 | W004° 37.821 | P-S 50° | 1000 | | D HP S | 1 | | | | | 15.04 | CW DS LT ID | 1 | Leaping | A T N | SP. |
| _5 | N52° 9.386 | W004° 37.396 | P-S 90° | 300 | | D HP S | 1 | | | | | 15.08 | CW DS LT ID | 1 | | A T N | AM |
| _6 | N52° 9.291 | W004° 37.819 | P-S 90° | 200 | 2mm | D HP S | | | | | | 15.10 | CW DS LT ID | 1 | | A T N | S.H |
| _7 | N52° 9.840 | W004° 38.636 | P-S 90° | 600 | | D HP S | 3 | | | | | 1525 | CW DS LT ID | 1 | | A T N | F.U. |
| _8 | N52° 10.155 | W004° 46.729 | P-S 30° | 120 | | D HP S | 5 | | | | | 1525 | CW DS LT ID | 1 | | A T N | F.U. |
| _9 | N52° 9.839 | W004° 38.630 | P-S 90° | 230 | | D HP S | 2 | 1 | | 1 | | 1810 | CW DS LT ID | 0 | | A T N | F.U. |
| _0 | N52° | W004° | P-S | | | D HP S | | | | | | | CW DS LT ID | | | A T N | |

Effort: Casual Watch, Dedicated Search, Line Transect or ID work
Behaviours. BND & HP- T: travel, SF: suspected feeding, FF: feeding (fish seen), O: other, N: unknown.
GRS- H: hauled out, S: swim
Direction (only BND & GRS) : Either degrees from compass or variable (VAR)
Boat reaction (only BND & GRS): swimming Away from us, Towards us or Neither

**Annex 3:** Encounter Sheet.



**BND Encounter Sheet** Record No.: 04. 022

Date 05 / 06 / 04 Boat SULAIRE Sighting ref 16 Enc. #__ Page 1 of 1

Person responsible of data F.U. Notes by S.P. Crew SH, SP, TF, KL, RL, J.L, F.U.

**Start:** Time 13.10 N 52° 07.825 W 4° 47.075 **End:** time 13.42 N 52° 07.567 W 4° 45.565

**No. of animals (best guess)** 14 Adults 12 Juveniles 2 Calves 0 NBs 0

Animals photographed ≃ 14 Adults 12 Juveniles 2 Calves 0 NBs 0

Subgroups: [14] Well marked: W0303 ?

__ Travel__ Probably feed __ Feed ✓Other__ Bowride __Leap__ Splash __Contact

Swimming direction _____ Comments Same group as earlier, plus more

Until time 13.42, @ N 52° 07.567 W 4° 45.565

Subgroups: Well marked:

__ Travel__ Probably feed __ Feed __Other__ Bowride __Leap__ Splash __Contact

Swimming direction _____ Comments ____________

Until time ______, @ N 52° ________' W 4° ________'

Subgroups: Well marked:

__ Travel__ Probably feed __ Feed __Other__ Bowride __Leap__ Splash __Contact

Swimming direction _____ Comments ____________

Until time ______, @ N 52° ________' W 4° ________'

Film no. 1 Start time _____ Spacer frame 20 of SERGI End frame 36 by SH

DIGITAL Film no. D Start time _____ Spacer frame ___ of ________ End frame _____ by FU

Film no. 2 Start time 13.10 Spacer frame 1 of SERGI End frame 36 by FU

Film no. 3 Start time _____ Spacer frame 1 of FORM End frame 7 by SH

**Annex 4:** Film Sheet.

## ID Film Sheet

Date 7 / 8 / 04 Records no. 90, 91 Film no. 67 By S.H.

IDs ENCOUNTER 90 - ID's W0306, W0307, W0376 W0393.

| Enc | Fr | Time | Quality | Marking | ID | Comments |
|---|---|---|---|---|---|---|
| 90 | 1 | 11.39 | X | | | FORM |
| | 2 | 11.48 | 3 | WM | | |
| | 3 | " | 2 | WM | | W0307 |
| | 4 | " | 2 | WM | | W0306 |
| | 5 | " | 4 | WM | | |
| | 6 | " | 2 | WM | | |
| | 7 | " | 4 | WM | | W0393 |
| | 8 | 11.49 | X | — | | |
| | 9 | " | 2 | WM | | W0393 |
| | 10 | " | 3 | WM | | |
| | 11 | 11.50 | 3 | WM | | W0306 |
| | 12 | " | 3 | WM | | W0376 |
| | 13 | " | X | — | | |
| | 14 | 11.51 | 3 | WM | | W0306 |
| | 15 | 11.54 | 4 | WM | | W0393 |
| | 16 | " | 4 | WM | | W0376 |
| | 17 | " | 4 | WM | | |
| | 18 | " | 4 | WM | | W0393 |
| | 19 | 12.00 | 3 | WM | | W0306+W0307 |
| | 20 | " | 4 | WM | | W0306 |
| | 21 | " | 3 | WM | | W0393 |
| | 22 | " | 3 | WM | | W0393 |
| | 23 | " | 3 | WM | | W0307+W0306 |
| | 24 | " | 4 | WM | | W0306 |
| | 25 | " | 3 | WM | | W0306 |
| | 26 | " | X | — | | |
| | 27 | " | 2 | WM | | W0307 |
| | 28 | " | 2 | WM | | W0393 |
| | 29 | 12.03 | 4 | WM | | W0376 |
| | 30 | " | 4 | WM | | |
| | 31 | " | 4 | WM | | W0306 |
| | 32 | " | 3 | WM | | |
| | 33 | " | 3 | WM | | W0393 |
| 91 | 34 | 12.54 | X | — | | FORM |
| | 35 | 12.55 | 4 | WM | | |
| | 36 | " | 3 | WM | | W0303 |

**Annex 5:** The results obtained from the ($M_{th}$) model for population sizes, using CAPTURE run through MARK v4.1, for the years 2003, 2004 and 2005, respectively.

## 2003

```
Input---title='2003 population'
Input---task read captures x matrix occasions=38 captures=38
Input---data='Group 1'
Input---format='(a6,38f1.0)'
Input---read input data

Summary of captures read
Number of trapping occasions       38
Number of animals captured         95
Maximum x grid coordinate         1.0
Maximum y grid coordinate         1.0

Input---task population estimate mth-chao
Population estimate under time variation and
individual heterogeneity in capture probabilies.
See model M(th) of Chao et al. (1992).

Group 1
Number of trapping occasions was         38
Number of animals captured, M(t+1), was    95
Total number of captures, n., was        435

Frequencies of capture, f(i)
i=   1   2   3   4   5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22
      23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38
f(i)=  16  15  12   8   9 10  7  6  6  3  2  0  1  0  0  0  0  0  0  0  0  0
       0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

   Estimator     Gamma    N-hat        se(N-hat)
   ------------------------------------------------
```

| | | | |
|---|---|---|---|
| 1 | 0.2830 | 103.33 | 4.22 |
| 2 | 0.2806 | 103.09 | 4.17 |
| 3 | 0.2807 | 103.10 | 4.17 |

p-hat(j) = 0.11 0.10 0.08 0.12 0.11 0.09 0.16 0.14 0.07 0.10 0.17 0.11 0.04 0.13 0.05 0.10 0.10

0.08 0.11 0.10 0.19 0.20 0.20 0.11 0.17 0.10 0.12 0.14 0.17 0.07 0.03 0.10 0.18 0.07 0.04 0.11 0.07 0.14

Bias-corrected population estimate is 103 with standard error 4.1719

Approximate 95 percent confidence interval 99 to 115

## 2004

Input---title='2004 population'

Input---task read captures x matrix occasions=32 captures=32

Input---data='Group 1'

Input---format='(a6,32f1.0)'

Input---read input data

Summary of captures read

Number of trapping occasions 32

Number of animals captured 82

Maximum x grid coordinate 1.0

Maximum y grid coordinate 1.0

Input---task population estimate mth-chao

Population estimate under time variation and

individual heterogeneity in capture probabilies.

See model M(th) of Chao et al. (1992).

Group 1

Number of trapping occasions was 32

Number of animals captured, M(t+1), was 82

Total number of captures, n., was 242

Frequencies of capture, f(i)

i= 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

32

f(i)= 22 26 13 6 4 6 1 0 2 0 1 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

| Estimator | Gamma | N-hat | se(N-hat) |
|---|---|---|---|
| 1 | 0.4618 | 101.38 | 8.15 |
| 2 | 0.4507 | 100.34 | 7.96 |
| 3 | 0.4513 | 100.39 | 7.97 |

p-hat(j) = 0.10 0.14 0.14 0.09 0.06 0.12 0.08 0.02 0.04 0.06 0.07 0.07 0.04 0.10 0.04 0.10 0.11

0.07 0.02 0.07 0.07 0.03 0.10 0.09 0.07 0.09 0.11 0.10 0.08 0.06 0.07 0.01

Bias-corrected population estimate is 100 with standard error 7.9722

Approximate 95 percent confidence interval 91 to 123

## 2005

Input---title='2005 BND population size'

Input---task read captures x matrix occasions=15 captures=15

Input---data='Group 1'

Input---format='(a6,15f1.0)'

Input---read input data

Summary of captures read

Number of trapping occasions 15

Number of animals captured 68

Maximum x grid coordinate 1.0

Maximum y grid coordinate 1.0

Input---task population estimate mth-chao

Population estimate under time variation and

individual heterogeneity in capture probabilies.

See model M(th) of Chao et al. (1992).

Group 1

Number of trapping occasions was 15

Number of animals captured, M(t+1), was 68

Total number of captures, n., was 115

Frequencies of capture, f(i)

| i= | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| f(i)= | 40 | 13 | 12 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Estimator | Gamma | N-hat | se(N-hat) |
|---|---|---|---|
| 1 | 0.2442 | 119.24 | 19.24 |
| 2 | 0.2141 | 114.56 | 18.28 |
| 3 | 0.2204 | 115.53 | 18.49 |

p-hat(j) = 0.16 0.02 0.13 0.04 0.15 0.06 0.05 0.10 0.06 0.05 0.02 0.03 0.08 0.02 0.03

Bias-corrected population estimate is 116 with standard error 18.4891

Approximate 95 percent confidence interval 91 to 167